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Investigation of New Organic and Organometallic Photocathodes in Vacuum and Gas Media for Photosensitive Gaseous Detectors

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Abstract: *Photocathode is an important component of gaseous detectors, which are instruments of choice for photon (gamma to visible range) detection. However, the main limitation is the degradation of photocathode used in such detectors at high radiation environment because of the heavy ion – bombardment. We have measured quantum efficiency of two new photocathodes were prepared from N,N′-Bis(3-methylphenyl)-N,N′-diphenylbenzidine (TPD) and 8-Hydroxyquinoline (Alq_3) compounds. In comparison, maximum QE was obtained with TPD whereas Alq_3 also showed better results. These photocathodes are air stable and easy to prepare. The obvious advantages of these photocathodes in gaseous detectors will be fast response and room condition operation.*

Keywords:*Gaseous Detectors, Photocathodes, Quantum Efficiency, Degradation, GEM*

I. Introduction

Efforts of photo sensors development of high quantum efficiencies and low energy thresholds coupled with gaseous detectors have been made since years [1, 2]. Promising applications for such devices are high energy physics experiments [3 – 6], detection of UV light produced by the scintillators [7, 8], nuclear physics [9, 10], medical imaging [11, 12], plasma diagnostic [13, 14], space sciences [15 – 18]. Earliest group of these devices comprised UV–photosensitive vapors filled wire chambers like (triethylamine (TEA), tetrakis–dimethylamino–ethylene (TMAE)) [19]. The modern era of fast, large in area, single photon imaging devices consist of reedy film of CsI photocathode fixedin gas avalanche photomultiplier [5, 20, 21]. The efficiency of photon detection of these devices, with in a given spectral range, dependent upon the quantum efficiency of the photocathode, the electron bouncing from the gas inthe photocathode [22] and the individual electron detection efficiency of the device [23].

The long term stability of gas avalanche photomultipliers is contingentto the photocathode.The photocathode gets degrades by chemical reaction of gas impurities [19, 24] or by accumulated influence of photons and avalanche–oriented ions bombardment on photocathode [7]. The photocathodes tested such as CsI [25], CsBr [25] and CVDdiamond films [26, 27] are moderately stable in terms of chemical properties. CsI can withstand short exposure to air which is very convenient in the process of assembling the detector. However, aging tests of CsI discoveredreduction in quantum efficiency of CsI photocathode for extremeradiation fluxenvironment, ageing datais in [28 – 30]. The main conclusion, which can be derived from previous studies, is that CsI aging depends on the experimental set up cleanness.

A further development, reported by different groups [31, 32], who used a protective adsorbed layeron the CsI of photocathode TMAE to improve the ageing properties of the CsI–TMAE photocathode. It was reported for CsI–TMAE photocathode that it is more stable under air exposure, and also found an increase in quantum efficiency as well. However, several groups [32] have reported the destruction of CsI–TMAE photocathode by the bombardment of positive ions.

More recent works [33 – 35] suggested the use of cascades of Gas Electron Multipliers (GEM), introduced by Sauli [36], which comprised of thin semitransparent or reflective solid UV and visible photocathodes which were introduced in Gas Electron Multipliers (GEM). However, the preliminary results of the photocathode aging under avalanche ion bombardment are not fully understood [37]. Also the long–term stability of Gas Electron Multipliers (GEM) in vacuum-packedmode, aging of photocathode under high gain conditions, feedback studies of ions in different gases and individual photon detection are still under exploration[38, 39]. The commercial availability of GEM foils is crucial since the production facilities of CERN are not sufficient; therefore, few attempts were also made at different production facilities [40, 41].

In order to improve the gaseous photomultiplier it is important to test new potential photocathode materials. The compound should be neither air–sensitive nor corrosive, and is easy to prepare as a solid photocathode.

In these work quantum efficiency (QE) results of N, N′-Bis (3-methylphenyl)-N, N′-diphenylbenzidine (TPD) and 8-Hydroxyquinoline (Alq_3) in solid phase are reported. Both of the photocathodes were prepared by vacuum evaporation technique using Edwards Auto 306 coating system. The obvious advantages of these photocathodes in gaseous detectors are their fast response and room condition operation.

II. Properties of Compounds

TPD [formula:[- C_6H_4-4-N(C_6H4CH_3)C_6H_5]$_2$] is solid at room temperature with vapour pressure 3.356 hPa at 25°C, and photoionization work function 5.5eV in solid phase. The molecular structure of TPD is shown in Fig 1.It is morphologically and thermally stable compound.

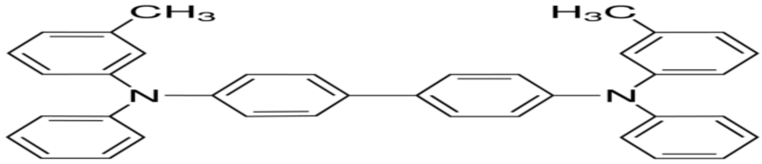


Fig1. Molecular structure of TPD

Alq_3[Empirical formula $C_{27}H_{18}Al\ N_3O_3$] is a yellow to green crystalline solid at room temperature with melting point 175-177°C and solid phase photoionization work function 5.8 eV. The molecular structure ofAlq_3 is illustrated in fig. 2. Both compounds were purchased from Sigma Aldrich Chemical Corporation LLC and were

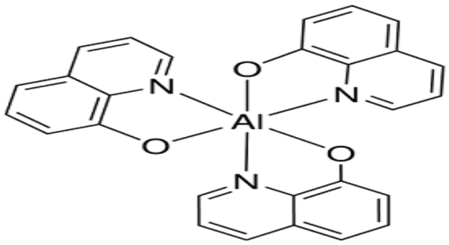


Fig. 2 The structure of ALq_3

used as it is. The molecular structure of N,N′-Bis(3-methylphenyl)-N,N′-diphenylbenzidine (TPD) and 8-Hydroxyquinoline (Alq_3), permits to combine them to required properties of low ionization potential and little chemical reactivity [42, 43]. Due to these reasons these compounds seems striking for use as photocathodes in gaseous detectors.

III. Experimental Technique:

In this work, DC current recording technique is used for quantum efficiency (QE) measurement of photocathodes under vacuum, therefore, the experimental arrangement consist of a prototype detector coupled with a solid photocathode, an ultraviolet photon source with sample and reference beams (SHIMADZU UV 1601 spectrophotometer), a reference detector for real time monitoring of the intensity of ultra violet (UV) radiation i.e. a photodiode (HAMAMATZU Photodiode No.S1723 – 05), a vacuum system for test chamber evacuation (BOC EDWARDS), electrometers for DC current measurement (KEITHLEY 6517A i.e. for test chamber and reference detector) and vacuum evaporator (EDWARDS 160 vacuum system and SIGMA SQM 160 for layer thickness measurement) . Experimental setup is schematically shown in fig 3.

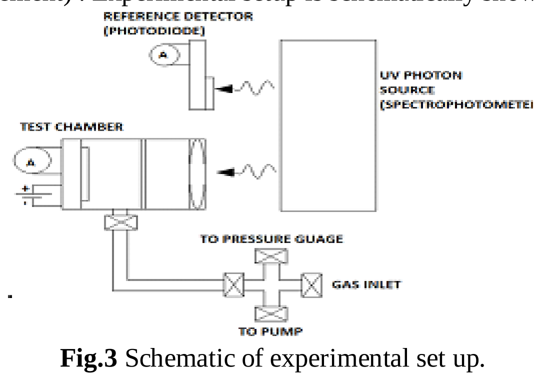
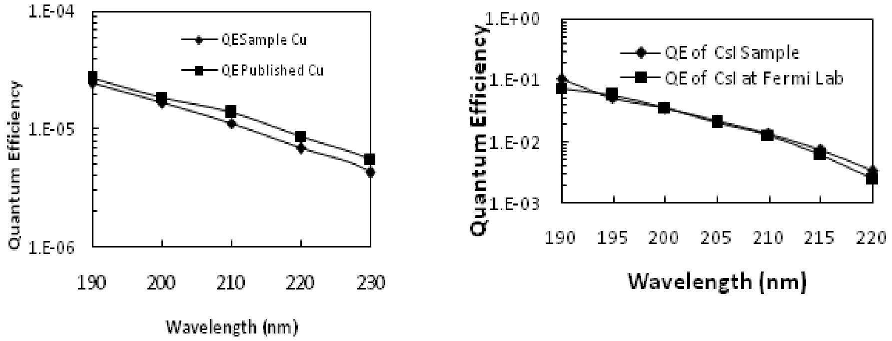


Fig.3 Schematic of experimental set up.

Initially the test chamber was calibrated by measuring the QE of bare copper substrate and 545 nm thick vacuum evaporated CsI photocathode and found reproduceable results of both the substrates which are in great agreement with results available(See fig.3a and fig.3b).



3a **3b**

Fig.3 (a) Comparison of QE Cu sample with Cu Published; (b) Comparison of QE of CsI sample with CsI published [45].

IV. Results and Discussion

The photocathodes of TPD and Alq_3 were prepared on borosilicate glass substrate by vacuum evaporationmonitor Sigma instruments (SQM-160).The photocathodes of different layer thickness of these materials were irradiated with UV photon source double beam spectrophotometer (Shimadzu UV-1601) in wave length range 190-250nm in vacuum at 10^{-4}Torr and showed non-negligible QE in the range190-230nm, it was observed that layer thickness has no notice able effect on the QE of the photocathodes. However, QE of the photocathodes of these materials when compared with bare copper photocathode, the layer effect was obvious. Comparison of the quantum efficiency of the 450nm thick photocathodes of TPD and Alq_3 are depicted in fig.4 (a) and 4(b) respectively.

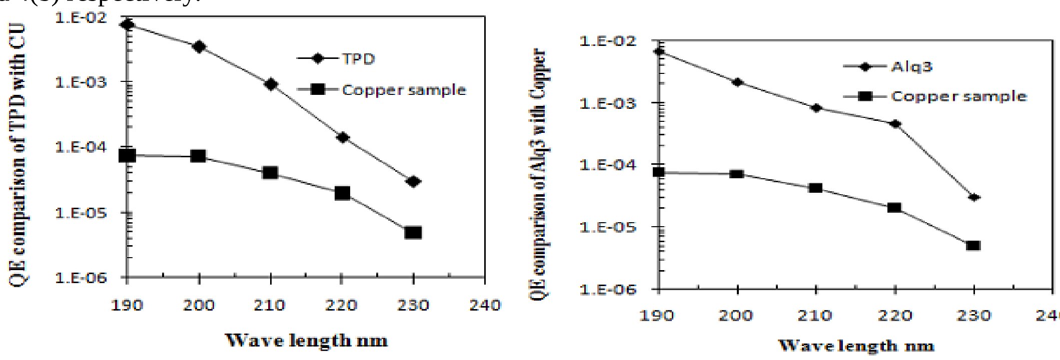


Fig.4 (a) Comparison of QE of TPD vacuum evaporated 450nm thick with copper sample(b) QE comparison of Alq_3 vacuum evaporated 450nm thick with copper sample.

QE of TPD and Alq_3 was also measured relative to most famous solid photocathode candidate CsI in spectral range 190-220nm. QE of the TPD and Alq_3 relative to CsI sample of same thickness fabricated and measured under same condition is illustrated in fig.5 (a) and 5(b) respectively.

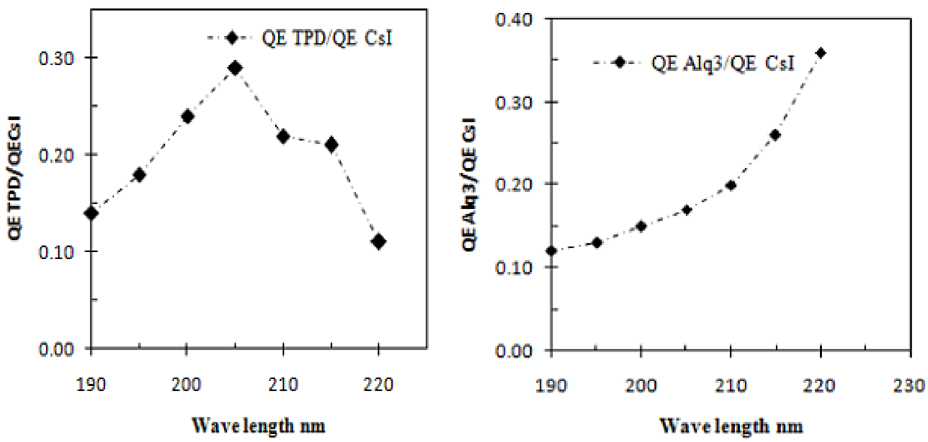


Fig.5 (a) QE of TPD relative to CsI sample in wave length range 190-220nm (b) QE of Alq_3 relative to CsI sample in wave length range 190-220nm.

It is evident from fig.5(a) that the QE of TPD as compared to CsI first increases 14% to 29% of the CsI in the range 190-210nm and then falls to 11% of the CsI at 220nm whereas QE of the Alq_3 increases from 12% to 36% of the CsI in the range 190-220nm. Moreover the two photocathodes are solid at room temperature, and are morphologically and thermally stable; characteristics suitable for detector construction and their QE also remained stable for several days.

V. Conclusion

Our results described in section 4 demonstrated that both the TPD and Alq_3 photocathodes have non-negligible QE in wave length range 190-230nm of the incident UV light. The photocathodes can survive in rough condition for several days and are suitable for room condition operation of the detector and therefore can find application in some high energy experiments. For this a detailed study of the ageing of these photocathodes is required.

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